A note on movements of two fin whales (*Balaenoptera physalus*) tracked by satellite telemetry from the Faroe Islands in 2001

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ABSTRACT

In August 2001, two fin whales were tagged with satellite linked radio transmitters 90km east of the Faroe Islands (62°N, 7°W). One whale that was tracked for 48 days resided on the Faroe shelf inside the 500m depth contour, with movements ranging within 190km from the tagging site. Another whale that was tracked for 116 days moved south to 46°N, 21°W, i.e. the same latitude as the Bay of Biscay, during the first 16 days of the tracking, which corresponds to a straight line distance of 2,830km. After residing at this latitude for three weeks, it moved northeast again, during two weeks, to an area north-west of Ireland. For the following two month period, it mainly moved within 54-58°N, at depths of 1,000-2,500m. A total of 132 positions were received from the two whales, most of relatively low accuracy, but still applicable for depicting large scale movements.

KEYWORDS: FIN WHALE; SATELLITE TRACKING; TELEMETRY; MOVEMENTS; NORTHERN HEMISPHERE; ATLANTIC OCEAN

INTRODUCTION

Knowledge about stock identity and migration of North Atlantic fin whales (*Balaenoptera physalus*) is limited (Donovan, 1991; IWC, 1992; 2007; NAMMCO, 2001). Fin whales migrate to feeding areas at higher latitudes in spring and summer, but are largely absent from the same waters in winter (Bloch *et al*., 2000). Although believed to have a more southerly distribution during winter (Sergeant, 1977), their wintering grounds in the North Atlantic are unknown. Genetic investigations at feeding grounds have suggested several independent populations across the North Atlantic, and indicated more than one breeding unit (Bérubé *et al*., 1998; Danielsdóttir, 1999; Daníelsdóttir *et al*., 1991). The stock boundaries accepted by the International Whaling Commission (IWC) in the mid-1970s divided the species into seven stocks or independent management units (Donovan, 1991; IWC, 1992). The division was based mainly on indirect evidence from former catch and sighting data (see Sergeant, 1977). Jonsgård and Rørvik (1975) concluded that fin whales in the waters around the Faroe Islands most likely belong to a West Norway – Faroe Islands stock. For fin whales in West Norway, more recent genetic studies have concluded that they are distinct from those taken in coastal waters of Iceland (Bérubé *et al*., 1998; Danielsdóttir, 1999; Daníelsdóttir *et al*., 1991). An earlier study comparing reproductive parameters (average length at sexual maturity, mean time of mating and parturition and pregnancy rate) also indicated that they were distinct from whales in North Norway (Haug, 1981). In 1982, 13 fin whales were marked with Discovery tags in Faroese waters. One mark was recovered 26 days later, near the tagging position (Bloch and Joensen, 1984). Fin whales from Faroese waters have so far not been included in any comparative population studies. The NAMMCO Working Group on Fin Whales concluded in 2000 that in order to give precise management options for fin whales in Faroese waters, and in North Atlantic in general, more information is needed on stock identity (NAMMCO, 2001). The more recent technical development of satellite transmitters, tracked by the Argos satellite-based data collection and location system, have given the opportunity to investigate *in situ* movements of marine mammals for extended time periods. Therefore, such studies may address questions about migration and site fidelity, and thus stock identity, of these animals. One major problem when tagging larger whales has been deployment techniques, since these animals cannot be handled during the tagging operation. However, new techniques for remote deployment of tags have recently become available (Heide-Jørgensen *et al*., 2001a). In 2000 and 2001 satellite tags were mounted on fin whales in Faroese waters, in order to study their movements and site fidelity. This paper describes movements of two fin whales successfully tracked using the Argos system.

MATERIAL AND METHODS

The satellite transmitters used in the study were of the type ST-15, manufactured by Telonics Inc., USA. These tags weighed 110g and were equipped with a saltwater conductivity switch only allowing transmissions when the switch was out of water. The tags were programmed to have a duty cycle of 24 hours actively transmitting followed by a 72 hour inactive period in order to prolong battery life. The repetition period was 45 seconds and the total number of transmissions each day was set to 500. Nominal longevity based on two M1 batteries was 25 days, but expected longevity with the programmed duty cycle was about 100 days. The tags were mounted to a 27cm long steel anchor bolt with barbs for penetrating the blubber and anchoring the tag at the surface of the body (see also Heide-Jørgensen *et al*., 2001b; Heide-Jørgensen *et al*., 2003). The equipment used for deploying the tags was the Air Rocket Transmitter System (see Heide-Jørgensen *et al*., 2001a; Fig. 1). Potential tagging localities for fin whales were selected from available observation and distribution data for the relevant time of the year (Bloch *et al*., 2000). Two procedures were used in the course of tagging. In 2000, fin whales were tagged from the LYNX helicopter located onboard the

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Danish fisheries inspection vessel *Triton* (112.3m), operating periodically in Faroese waters. Whales were discovered from the helicopter, re-spotted under the surface, and as the whale broke the surface, usually on the third blow, the helicopter dove and from an altitude of ca. 25m a tag was shot in the back of the whale (Fig. 1). In 2000 and again in 2001, fin whales were tagged from the Faroese fisheries inspection vessel *Tjaldur* (44.5m). A platform was constructed on the bow of the vessel from which the tags were fired (Fig. 1). The ship carefully tracked and approached whales, and when a whale was surfacing at a suitable distance (<30m), a tag was shot into the back of the whale. Effort was made to place the tags as high as possible on the back (near the centre line), in the area midway between the blowhole and the dorsal fin, to increase the probability of the antenna and salt-water switch being dry when the whale surfaced.

Satellite transmitter data were made available from Argos Data Collection and Location Service (*www.cls.fr*). The location data varied in accuracy, as indicated by the location class provided by Argos. In order to predict accuracy of locations (i.e. location classes 3, 2 or 1), the Argos receiving unit needs, among other transmission standards, a minimum of four uplinks during one satellite pass, lasting on average 10min. The accuracy of these locations is in 68% of cases given to be within 1,000m from actual transmitter locations. For less accurate locations (i.e. location classes 0, A or B) no predicted accuracy is given by Argos. Experimental studies have shown that location class A may have about same precision quality as location class 1, but that location classes 0 and B can have very low precision, although in most cases not exceeding 10,000m (Hays *et al*., 2001; Raum-Suryan *et al*., 2004; Vincent *et al*., 2002). In the present study no filter processing in order to identify erroneous locations (e.g. Austin *et al*., 2003; Vincent *et al*., 2002), was applied to the data. Movements are presented by the most accurate location or average of most accurate locations given each fourth day (i.e. duty cycle of transmitters). By this method, large errors from aberrant locations are reduced and estimated swimming speed is also less biased, since influence from low accuracy will be most significant when locations are close (Heide-Jørgensen *et al*., 2001b; Heide-Jørgensen *et al*., 2003).

RESULTS

All tagging attempts were conducted in good weather conditions in July and August, on the shelf and slope east and southeast of the Faroes. A total of 11 fin whales were equipped with satellite transmitters; five tagged from helicopter and two from vessel in 2000, and four tagged from vessel in 2001. One tag, fired from helicopter in 2000, missed the target and was lost. Two tags, mounted on 7 and 8 August 2001, within the same area 90km east of the islands, gave useful uplinks to be received and identified by the Argos data collecting system.

A total of 132 locations were obtained from the two whales, of which 125 (95%) were of unknown accuracy, i.e. location class 0, A or B (Table 1). In three incidents, when transmitters were active, no location was obtained, the longest gap being 12 days between subsequent locations. The average number of locations obtained each active transmitter day was 3.4 (range:0-11) for the two transmitters combined; both with similar performance.

The two active tags provided signals for total periods of 48 and 116 days respectively (Table 1). During the tracking period, these two whales showed different movement patterns. The whale with the shorter track (ID no. 20685) stayed on the shelf inside the 500m depth contour during the total 48 day tracking period (Fig. 2). Within the first four days of tracking, it moved to the southern part of the shelf, then turned and moved northeast again. For the rest of the tracking period, it stayed east of the Faroe Islands. When contact was lost, it was 80km west of the tagging site. The

Fig. 1. Fin whale is being approached by helicopter, ready to tag (above), platform arrangement on bow of M/S *Tjaldur* (middle) and typical position and angle of tag when fired from ship (bottom).

Table 1

The period of tag operation, distance travelled, speed and location quality for two fin whales tagged on 7 and 8 August 2001 (day 218/219) in Faroese waters. Standard deviation is given in parentheses. The given ARGOS accuracy of positions with location class 3 = 0-150m, 2 = 150-350m, 1 = 350-1,000m and for 0, A and B = accuracy not given.

ID no.	Tracking period	No. of days	No. of positions	Total distance travelled (km)	Daily horizontal speed	Distribution of positions by accuracy quality (location class)					
						3	2	1	0	A	B
20685	08/08/01-25/09/01	48	29	724	15km day^{-1} (17)	-	-	-	-	13	16
26712	07/08/01-01/12/01	116	103	9,279	80km day^{-1} (116)	1	1	5	5	16	75

total distance travelled was 724km, but geographically restricted within a range of 200km. The average daily movement was 21km (range 5-61km day^{-1}).

The whale tracked for the longer period (ID no. 26712) made a long southbound movement. After tagging it started moving southeast (Fig. 3), and was tracked south to 47°N, 27°W; i.e. approximately the same latitude as the northern part of Bay of Biscay. This movement covered 2,830km in 16 days and was confirmed by location class 3 and 2 positions. The average surface swimming speed, during the movement from the tagging site south to 47°N was 177km day^{-1}. The whale stayed at this latitude for a month, first moving east and then west again, towards the same location it had 32 days earlier. Thereafter it moved in a north-east direction, and fourteen days later it was located in an area north-west of Ireland (56°N, 12°W). For the next two months, until contact was lost, it stayed northwest of Ireland, with circular motions in an area of 400km, with steep slope and depths of 1,000-4,000m. The total distance travelled was 9,279km. The average daily movement for the whole period was 82km (range 9-447km day^{-1}).

DISCUSSION

Both the helicopter and large vessel were useful platforms for remote tagging of fin whales in Faroese waters, where tags were applied from distances up to 25m. However, whilst the helicopter was useful in high density areas, where at best four tags could be deployed during a one-hour flight, all of the tags deployed from the helicopter failed, probably

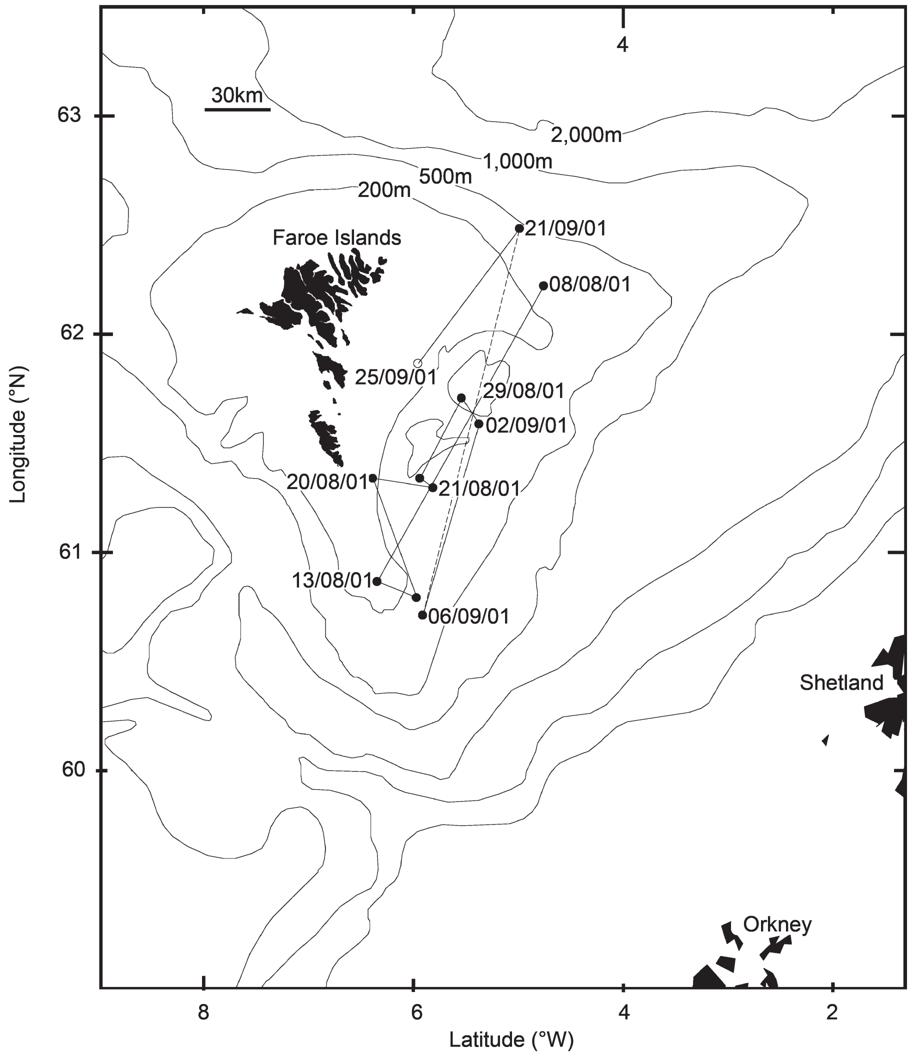

Fig. 2. Movements of a fin whale (ID no. 20685) tagged in Faroese waters 8 August 2001 and tracked until 25 September (48 days). One location is given every fourth day (dashed lines indicates when consecutive positions are apart by more than one 4-day period).

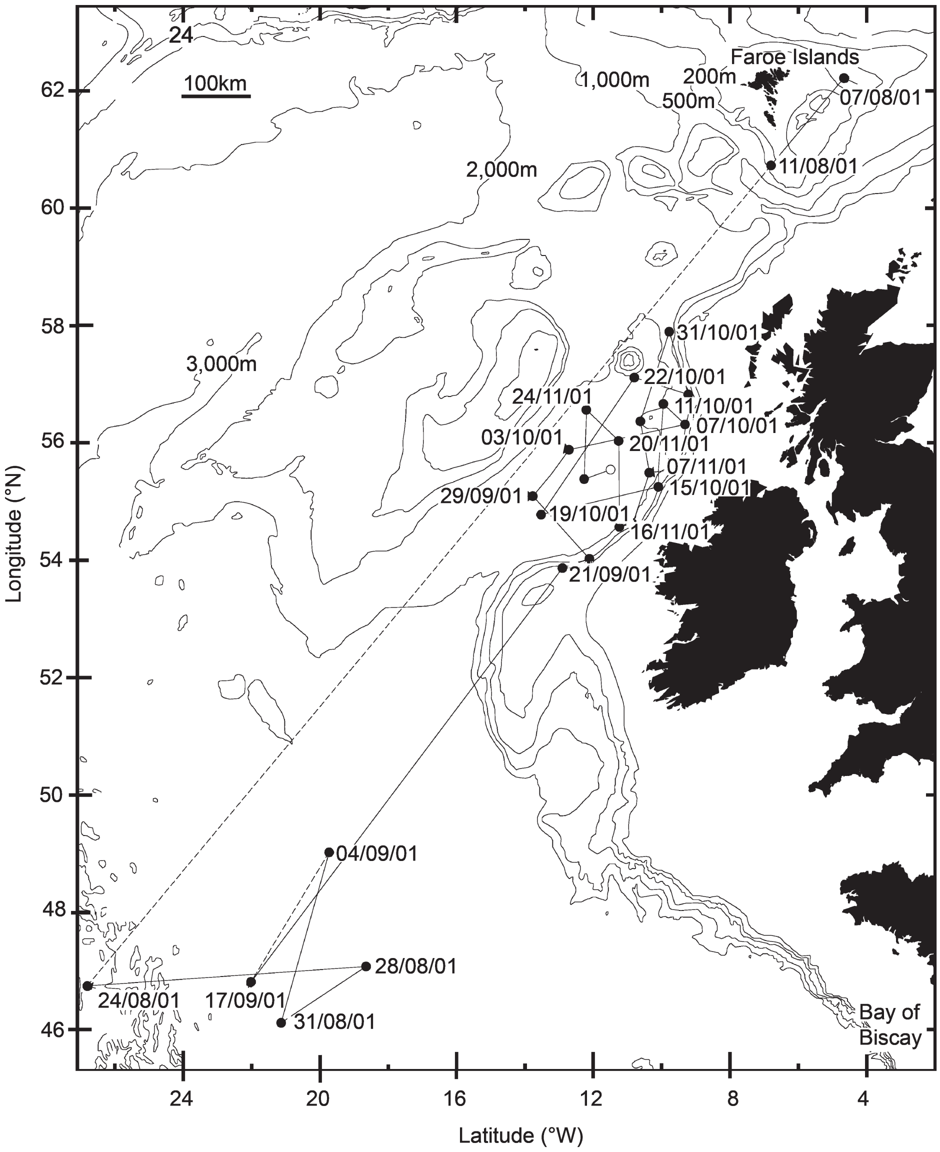

Fig. 3. Movements of a fin whale (ID no. 26712) tagged in Faroese waters 7 August 2001 and tracked until 1 December (116 days). One location is given every fourth day (dashed lines indicates when consecutive positions are apart by more than one 4-day period).

as a result of the heavy impact caused by the extra speed caused by the altitude of the helicopter. Observed problems with longevity of tags have been battery drainage or quick tag expulsion (Heide-Jørgensen *et al*., 2001b; Watkins *et al*., 1996), but in this study the problem seemed to be that tags could not stand the mechanical stress of firing or of hitting the whale body. One tag detached from the anchor bolt after being launched. In an attempt to solve this problem, tags were mounted using a long rod (Heide-Jørgensen *et al*., 2003). One tag attained expected battery longevity, while one tag stopped transmitting before expected battery exhaustion, perhaps because it fell off.

Tags were kept small, in order to reduce drag and use the ARTS launching gun, the trade-off being battery capacity. Tag longevity was prolonged from the nominal 25 days to above 100 days by only allowing transmission when a whale surfaced, creating a 25% duty cycle and limiting the number of transmissions each day. One position each fourth day was considered adequate for generalised large-scale tracking of fin whales in the Faroes. Therefore, an average of 3.3 locations transmitted each day fulfilled the objective of the study, although 95% of all locations had a relatively low precision. The reason for this was low uplink frequency, bad uplink quality or non-optimal distribution of uplinks across the Doppler curve. Information on precision (i.e. standard deviation of distributions within each location class) is only available when four or more uplinks are received for each satellite pass, lasting about 10min (Austin *et al*., 2003). Low uplink frequency may be caused by low surfacing times. Stone *et al*. (1992) reported a respiration rate of 48 breaths h^{-1}, a surface duration of 55s and a blow rate of around 3 for fin whales from Gulf of Maine. Assuming this respiration behaviour, the tracked whales may have been at the surface on average 10 times during a satellite pass. With a repetition period of 45s, this would allow the tag to transmit at blow one and again at blow three. The more likely problem with low uplink frequency could be because tags were placed low on the back of the whales, i.e. close to the waterline. Not being out of the water when the whale surfaced, the saltwater switch would not dry and let the tag transmit. This may be especially true during bad weather. Fin-mounted tags on pilot whales from the same area have performed better (Bloch *et al*., 2003), which could be because tags mounted on the dorsal fin may shed water quicker than tags mounted on the back.

Satellite tracking of large cetaceans usually provides locations with low accuracy (e.g. Heide-Jørgensen *et al*., 2006; Heide-Jørgensen *et al*., 2003; Mate *et al*., 1999) and the consequence of using such data may be misleading tracks and unrealistic speed estimates (Austin *et al*., 2003; Mate *et al*., 1999). In the present study, 69% of all positions were of location class B, which implies low accuracy. Experimental studies have demonstrated that most Argos locations with low accuracy still lie inside 10,000m from true location (Hays *et al*., 2001; Vincent *et al*., 2002). Since location data were only available every fourth day, swimming speed estimates were averaged for each 4-day period, which reduced the impact from erroneous locations (Heide-Jørgensen *et al*., 2003). The purpose of the present study was large-scale tracking of fin whales in the North Atlantic. Creating a 4-day transmitter cycle gave useful tracks, although smaller-scale details were lost.

Fin whales can be observed in Faroese waters year round, but they are mainly present from mid-July to mid-October (Bloch and Ofstad, 2000). They are most frequently encountered in the slope area around the shelf (Bloch *et al*., 2000). Whale 20685 was relatively stationary on the shelf, at depths less than 500m, for one and a half months in summer. It was mainly moving in the area where a thermal boundary between shelf and Oceanic water is located (Hansen, 1985); an area rich in both plankton (Gaard, 2000) and pelagic and demersal fish species (Jákupsstova, 2002;2004). Fin whales are relatively frequently encountered in this area (Bloch *et al*., 2000), which was most likely a feeding ground for the whale. Whale 26712, tracked for nearly four months, left the Faroes shelf immediately after tagging and moved south to the deep waters east of the mid-Atlantic ridge, midway between the Faroes and the Azores. In these waters, 3-4,000m deep, its behaviour was the most dynamic, swimming at high speed in different directions during the entire track, perhaps because prey patches were not frequently encountered. After 12 days, it started moving northeast again, following the continental slope west of the British Isles. This part of the route confirmed a common movement pattern seen for the species, which often is associated with bathymetric features deeper than 1,500m (Heide-Jørgensen *et al*., 2003; Panigada *et al*., 2005; Watkins *et al*., 1996). Upon reaching the area northwest of Ireland, whale 26712 moved with slow swimming speed for the next two months in a fairly defined patch, presumably feeding in the slope waters.

The present study has demonstrated that fin whales are capable of moving long distances in the North Atlantic quickly. Watkins *et al*. (1984) observed, when tracking a fin whales from Iceland towards East Greenland during 9.5 days, an average swimming speed of 7.4km h^{-1}, which equals the swimming speed of whale 26712 during the first 16 days of tracking. A swimming speed of greater than 7km h^{-1} for an extended time has been demonstrated for blue whales (*Balaenoptera musculus*) (Mate *et al*., 1999). Whether or not this is a consequence of a short-term tag effect, as hypothesised by Mate *et al*. (1999), is unclear, but this directed swimming speed was not observed for whale 20712. The effect of tagging is considered minor on fin whales (Watkins *et al*., 1996), at least when only penetrating the blubber.

Watkins *et al*. (1984) found, from their track of a fin whale in Icelandic waters, evidence for east-west movements and mixing between fin whales in Icelandic and Greenlandic waters, while the tracking of two fin whales in Greenlandic waters by Heide-Jørgensen *et al*. (2003) gave evidence for a connection between fin whales in inshore and offshore waters. The present study is the first direct evidence that mixing occurs between the Spain-Portugal-British Isles stock of fin whales and fin whales around the Faroe Islands. Whale 26712 moved from Faroese waters in August, but in December was still present at 55°30'N. This suggests that the observed movement was not the onset of the migration towards a wintering ground. The observation that fin whales remain in northern North Atlantic waters until at least the onset of winter is an interesting discovery, although perhaps not uncommon (Bloch, 1998).

The present study has indicated that fin whales around the Faroe Islands may be a northern component of the Spain-Portugal-British Isles stock of fin whales. This contradicts a proposed Faroe-West-Norway stock of fin whales (Donovan, 1991; Jonsgård, 1966; Jonsgård and Rørvik, 1975) and may indicate the presence of only one stock in the southern waters of the eastern North Atlantic, as suggested for the south-western side of the North Atlantic (IWC, 1992), which is certainly a future prospect for investigation.

It could be that Faroese waters, by their location, act as migration corridor for surrounding fin whale stocks when moving to and/or from their summering grounds. If so, site-fidelity for fin whales in the area would be weak, perhaps also a response to fluctuating environmental conditions, such as high annual variations in primary production, notably in Faroese waters and affecting all trophic levels (Gaard *et al*., 2002). This may result in more plastic movement patterns among the whales utilising the Faroese waters for feeding. Satellite tracking has proven a promising method for gaining insight into fin whale movements and seasonal distribution, which can provide important information for evaluating the stock structure of fin whales in North Atlantic.

ACKNOWLEDGEMENT

We thank Lars Kleivane, Mikkel Villum Jensen, Eyðfinnur Stefansson and Bjørki Geyti for their well executed work during tagging. Thanks also to the crew onboard M/S *Triton* and M/S *Tjaldur* for their excellent cooperation during tagging operations and to Lise Helen Ofstad for preparing the maps. This study was funded by Ministry of Fishery and Maritime Affairs, Faroe Islands and the Greenland Institute of Natural Resources.

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Date received: April 2006
Date accepted: February 2007